EXCHANGE OF LYOTROPIC SERIES CATIONS BY MICACEOUS VERMICULITE
AND ITS WEATHERING PRODUCTS DETERMINED BY ELECTRON MICROSCOPY
AND RADIOCHEMICAL ANALYSIS

Progress Report

Marion L. Jackson and Philip A. Helmke

MASTER

University of Wisconsin
Madison, WI 53706

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

August 1, 1974 - October 31, 1977

(3-year report)

PREPARED FOR THE U. S. ENERGY RESEARCH AND DEVELOPMENT
ADMINISTRATION UNDER CONTRACT NO. EY-76-S-02-1515

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED *eb*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed or represents that its use would not infringe privately owned rights.

TECHNICAL PROGRESS REPORT

Marion L. Jackson -- Principal Investigator
and
Philip A. Helmke -- Co-Investigator

Contents:

	<u>Page</u>
Abstract (200 words or less)	3
Documentation and Collaboration	4
I. Measurement of cation retention, surface layer charge, U and other trace element concentrations, and age of micas weathering to vermiculite	5
a. Layer charge by exchange saturation with uranyl cations, thermal neutron activation of ^{235}U , and fission particle track counting	5
b. Layer charge decrease during weathering	8
c. Thermodynamic metastability of micaceous vermiculite in soils	8
d. Uranium concentration and age determination by neutron activation of native ^{235}U in micas formed in soil	9
II. Studies of fission product adsorption and fixation processes and structures	11
a. Specific adsorption of divalent cations of the alkaline earth type and transition and heavy metal types by hydrous iron and aluminum oxides	11
b. Retention of multielement sequences by instrumental neutron activation analysis to evaluate potential fission product element retention	14
c. Layer sequence of phyllosilicate structures by high resolution electron microscopy in relation to cation fixation	19
III. Aerosolic minerals in dusts which fix radioactive nuclear fission products	21
a. Oxygen isotopic tracing dust origin	21
b. Scanning electron microscopic identification of dust components	22
c. Major aerosolic dust systems	23
d. Neutron activation analytical tracing of dust origin	29
Publications	30
Manuscripts submitted for publication	31
Manuscripts in preparation	32
Key to C00-1515 report series	33
Effort level of permanent personnel	34

Abstract
(200 words or less)

Determination of layer charge of micas by ^{235}U fission particle tracks (thermal neutron activated) was completed by a development of a unique method of UO^{2+} saturation at pH 2.4 and removal of excess salts physically. The U content and age-dating of soil micas was also accomplished by fission particle counting. Thermodynamic metastability of micaceous vermiculite in soils with reversible mica-vermiculite reactions were found to result in extremely tenacious natural fixation of Cs^+ in soil fine fractions and weathering rock, a model for $^{137}\text{Cs}^+$ retention. Visual models for Cs^+ fixation were obtained as structural layer images of micaceous vermiculite wedges in clays, including kaolinites.

Diverse divalent cations were found to adsorb specifically (i.e. in 1M NaNO_3) on hydrous oxides of Fe and Al, materials common in soils and capable of "holding up" $^{90}\text{Sr}^{2+}$, $^{45}\text{Ca}^{2+}$, and other fission products from free movement in groundwaters.

Aerosol size quartz (1 to 10 μm), from dusts containing Cs^+ fixing micaceous vermiculites, was characterized by oxygen isotopic ratio analysis and the ratios found useful in tracing dust provenance. Quartz of chert origin was revealed electron microscopically as clusters of fine subhedral crystals. Of the 20 elements measured in Cretaceous shales La, Sm, Ba, and Hf showed trends in concentration from igneous shore line to central basin, correlative with change in oxygen isotopic ratio.

Documentation and Collaboration

This progress report is submitted pursuant to Article B-XXI of the Contract, No. EY-76-S-02-1515 which has been in operation since June 1, 1965. Under this contract to July 26, 1977, 45 scientific papers have been published (four reprints are attached) or accepted for publication, six additional papers have been submitted for publication, and eight others are in various stages of development for publication (all listed near the end of this report). During the time the contract has been in force nine Ph.D. students have worked on the project (8 now placed in jobs) and 13 Post-doctoral Project Associates have participated in the work at Madison. Numerous other scientists, on campus and off-campus throughout the world have actively participated in the research, through an International Consortium for Interinstitutional Cooperation in the Advancement of Learning (ICICAL) organized by the Principal Investigator. Major cost-sharing has been achieved because of the interest in cooperating with this project of people who are otherwise supported. Significant research results have been obtained through this collaboration, including co-publication with the collaborators (resulting publications, with co-operating authors, are listed near the end of this report). The C00-1515 reporting status is summarized in the last two pages of this report.

I. Measurement of cation retention, surface layer charge, U
and other trace element concentrations, and age of micas
weathering to vermiculite

a. Layer charge by exchange saturation with uranyl cations, thermal
neutron activation of ^{235}U , and fission particle track counting. Natural
 ^{238}U fission particle tracks were shown to give access to K^+ and $^{137}\text{Cs}^+$
to fixing sites in the interior of micaceous vermiculite (Lee, Jackson,
and Sachs, 1974).^{*} The track density was observed to be 200 to 500 cm^{-2} .
This may account in part for the efficiency of natural micas in rocks
(shales, saprolites, etc.) in retaining Cs (Section IIb). The tracks
become visible with scanning electron microscopy after HF etching of the
micas (Jackson et al., 1973). Therefore, a 235 , ^{238}U replica method for
the determination of surface layer charge density of mica was developed
(Lee and Jackson, 1977). The method consists of saturation of the
surface by washing with 0.5M $\text{UO}_2(\text{NO}_3)_2$. The excess UO_2^{2+} is removed by
washing with 0.01M $\text{UO}_2(\text{NO}_3)_2$ in 0.005M HNO_3 solution (pH 2.4), a solution
composition which prevents hydrolysis of the UO_2^{2+} to $\text{U}_2\text{O}_5^{2+}$ and $\text{U}_3\text{O}_8^{2+}$
in the pH range of 2.5 to 6. The excess dilute salt is removed by
pressing between dry filter paper three times. That a negligible amount
of excess salt from the dilute washing solution remained was established
by coverglass controls. To standardize HF etching time, the fission

^{*}(Authors, date) refers to publications or manuscripts accepted for
publication, given in the first list of references appended. (Authors,
date, submitted) refers to manuscripts submitted for publication, in the
second list of references appended. (Authors, in preparation) refers to
manuscripts in the process of being prepared, in the third list of
references appended.

track replica method on muscovite was employed. The mica in contact with the muscovite was subjected to thermal neutron activation, the muscovite etched and the tracks counted (Jackson, Lee, Ugolini, and Helmke, 1977). The exchangeable UO_2^{2+} cations retained (mean $3.6 \pm 0.2 \times 10^{-7}$ meq cm^{-2} , Table 1), on the cleavage surfaces of various micas were nearly equal to the theoretical surface charge (CEC, 3.5×10^{-7} meq cm^{-2} ; Mokma et al., 1970). This method appears to be simple, sensitive, and fast as compared to conventional methods. It is especially valuable because it minimizes error arising from structural defects at broken edges, a problem encountered earlier (Mokma et al., 1970).

Uranyl cations in the interlayers near broken edges of the crystal layers were strongly retained, and therefore these areas were avoided by track counting on the clear planar surface areas. Increase of uranyl concentration in the washing solution led to an retention of excess salt on the surface (Table 1). Uranyl cations replaced much of the interlayer cation population of vermiculite, even when the vermiculite was pre-saturated with K, Rb, or Cs and dried at 110°C (Table 1).

Strong adsorption of uranyl cations (not replaced by Ca^{2+} of neutral salt solutions) which occurred in the defects of micas and in the vermiculite interlayers is important because these minerals are extensive in soils and sediments. Analogous behavior of the actinide elements including Pu is important in the action of soils as barriers to reactor product entry into the ground water and the food chain. Further work on the retention of actinides by micaceous vermiculite is proposed.

Table 1. Uranyl cations retained on the surface of micas and vermiculites after washing with two dilute uranyl solutions

Samples	Source	UO ₂ ²⁺ retained on surface after washing with	
		Solution A* (10 ⁻⁷ meq cm ⁻²)	Solution B†
<u>Micas:</u>			
Muscovite	Mitchell, NY	5.01	3.66
Muscovite	Unknown	4.70	3.74
Lepidolite	Western Australia	4.87	3.27
Biotite	Bancroft, Ontario	5.34	3.87
Phlogopite	Herimer, NY	5.33	3.61
Lepidomelane	Faraday, Ontario	4.97	<u>3.34</u>
Mean ± Std. Deviation (1 sigma) 3.58±0.23			
<u>Vermiculites:</u>			
K-vermiculite	Transvaal, South Africa		12.48
K-vermiculite	Libby, MT		14.59

*Solution A; 0.02 M UO₂(NO₃)₂ in 0.005 M HNO₃.

†Solution B; 0.01 M UO₂(NO₃)₂ in 0.005 M HNO₃.

b. Layer charge decrease during weathering. Layer charge decrease in micaceous vermiculites is an important aspect of cation exchange of fission products. The charge lowering was shown to arise from mechanisms other than oxidation of structural Fe^{2+} because a proton is lost from structural OH^- concurrently with the oxidation, shown for the first time in neutral aqueous suspensions (Veith and Jackson, 1974). The mica layer charge may depart from theoretical by several percent because of excess OH^- or $\text{O}^{=}$ content (Eugster and Wones, 1962; Foster, 1964; as reviewed in Veith and Jackson, 1974). Layer charge decrease was shown to take place by Si substitution for tetrahedral Al and Fe in phlogopitic mica weathering to vermiculite and saponite (Sridhar and Jackson, 1974). Sequences of a few layers to saponite formed in phlogopite was shown, by scanning electron microscopy, to have taken place within numerous partings of each vermiculite flake (Jackson and Sridhar, 1974). The Mg of the octahedral sheet remained intact, possibly because of the high Mg concentration within the confines of the 4 Å inter-layer space as mica formed vermiculite. The alteration to saponite appeared to be nucleated in isolated spots (identified as blisters; Sridhar and Jackson, 1973).

c. Thermodynamic metastability of micaceous vermiculite in soils. The effect of the partial pressure of CO_2 (simulating seasonal changes in soil atmospheres) on micaceous mineral release and fixation of K^+ , and by analogy of $^{137}\text{Cs}^+$ and other fixing cations in soils, was worked out by a study of steady-state reactions in aqueous suspensions of Harps, Clarion, and Blount soils of the Mid-West (Henderson, Doner, Weaver, Syers, and Jackson, 1976). The rates of the cation release-fixation reactions are fast, compared to clay weathering reactions that produce kaolinite, so that the mica-

vermiculite reaction could be treated thermodynamically as an equilibrium reaction. The high rate of K^+ fixation found for the natural micaceous vermiculite of soil is important to effective retention of fixing cations of nuclear wastes (Section IIb).

d. Uranium concentration and age determination by neutron activation of native ^{235}U in micas formed in soil. Age determination of small mica flakes, obtained from horizons of cold-region soil samples from Antarctica, was undertaken by the fission track method. Studies by the standard fission track method showed that the mica flakes were too fragile to survive the HF etching treatment, and thus the replica method was used. The fine mica was placed in layers greater than 20 μm thickness to maximize fission track density on the replicating muscovite substrate (Jackson, Lee, Ugolini, and Helmke, 1977). After thermal neutron activation, the substrate was etched with HF and the fission tracks counted on the low-U muscovite substrate. The U content of mica in the fine sand fraction was most easily determined. The spontaneous fission tracks of the clay fraction was determined by ^{235}U activation replica tracks, on the basis that the spontaneous tracks were the same, per unit of U, as the fine sand flakes. The results from all size fractions were then consistent.

An age of 4.1 ± 0.2 million years was obtained on small mica flakes from several soil horizons. By this new method, the pedogenic micas of the Antarctic soil were found to contain 0.5 to 1.6 ppm of U, which is 20 to 50 times higher in uranium than the biotite mica of the parent igneous rock (0.03 ppm). This concentration of uranium by weathering may be of significance to understanding and prospecting for uranium energy resources. This age is somewhat greater than the minimum time since the Vanda (latest)

glaciation in the Wright Valley, based on K-Ar dating. The dioctahedral mica flakes appeared in thin-sections to have developed as K mica replacement of plagioclase feldspar grains, increasing from subsoil to surface soil. A method of mounting the fine fractions so that their ^{238}U (spontaneous) track counts can be made is proposed for study. The method is expected to be of help in U fuel exploration.

II. Studies of fission product adsorption and fixation processes and structures

a. Specific adsorption of divalent cations of the alkaline earth type and transition and heavy metal types by hydrous iron and aluminum oxides.

Important to fission product "hold-up" from flow with groundwater are the findings that trace amounts (10^{-6}M) of $^{90}\text{Sr}^{2+}$ and $^{45}\text{Ca}^{2+}$ are adsorbed strongly by hydrous oxides of iron and aluminum (such as occur in soils), even in the presence of 1M NaNO_3 (Kinniburgh, Syers, and Jackson, 1975). Specific adsorption of zinc and cadmium was found to occur on hydrous oxides of iron and aluminum 10^{-3} to 10^{-7}M concentrations in 1M NaNO_3 (Kinniburgh, Sridhar, and Jackson, 1976). These results, when presented before the 15th Symposium at Battelle, created considerable interest because many workers were puzzled as to why 1M salts did not replace traces of divalent metals. Evidently, a coordination bonding of $(\text{Fe,Al})\text{-O-M}^{2+}$ is established at the gel surface, which renders a whole series of the M^{2+} cations irreplaceable by M^+ . The divalent cations are, however, replaceable by H^+ below a cation-specific pH (Kinniburgh, Jackson, and Syers, 1976).

The adsorption of alkaline earth, transition and heavy metal cations occurs even when hydrous oxide gels are positively charged, i.e. the adsorption is "specific" and occurs over varying pH ranges (pH 3 to 9) for different cation types. This specific adsorption occurs well below cation concentration limits set by solubility products of the divalent cation hydroxides, and at low fractions of hydroxide complexing ($\ll 1\% \text{MOH}^+$). Although chloride forms strong complexes with Hg, chloride does not enhance the adsorption of Hg(II) (Kinniburgh and Jackson, 1977, submitted; Fig. 1). The presence of acetate enhances ^{65}Zn adsorption but the presence of chloride

Fig. 1 -- Hg(II) and Cl adsorption by Fe gel (0.001M in Fe), as a function of final pH, from a solution containing 1×10^{-6} M Hg, 4×10^{-6} M Cl, and 1M NaNO_3 . The experimental chloride adsorption is compared with that calculated on the assumption that all mercury complexes are adsorbed according to their initial concentration in solution.

does not. Although only one H^+ was released to solution per cation of the ^{90}Sr or ^{45}Ca type adsorbed, 1.7 H^+ were released per ^{65}Zn ion adsorbed (Kinniburgh and Jackson, in preparation). Specific adsorption, by iron and aluminum gels common to soils, of a wide range of cations present in fission products has significance for the movement of these contaminants in ground waters, and completion of this work is proposed.

Highly sensitive methods for the determination of aqueous trivalent ion species such as Al^{3+} and Fe^{3+} at concentrations down to 0.1 ppb ($1 \times 10^{-10} g cm^{-3}$), is under study (May, Helmke, and Jackson, in preparation). These methods are expected to be useful for studies of water composition in relation to soil reactions, reactor corrosion, mine spoils drainage, and other areas of concern in energy research and development.

b. Retention of multielement sequences by instrumental neutron activation analysis to evaluate potential fission product element retention.

To evaluate the retention of radioactive waste elements by soils, the behavior of elements in profiles of weathered diabase and granite rock systems, extending down into the saprolite (weathered rock, largely in place), were measured by instrumental neutron activation analysis (INAA) (Koons and Helmke, 1977, submitted) and X-ray fluorescence (XRF). Samples were separated into different size fractions by dispersion in water. Additional mineral separations were carried out with heavy liquids and a magnetic separator followed by hand-picking when the mineral grains were large enough. The minerals have been identified by X-ray diffraction and optical microscopy. Comparison of the results from samples of fresh and weathered rocks show that of all the elements determined, Cs is the least mobile during the weathering process (Fig. 1) for both series of rocks. The Cs is preferentially bound in the smallest size fraction (Fig. 2). Sericite (secondary fine-grained muscovite formed from weathering of plagioclase; cf., Jackson, Lee, Ugolini, and Helmke, 1977) is present in both rock series and biotite is present as an original mineral in the diabase series. The ability of micaceous vermiculite to fix Cs^+ strongly suggests that these micas are the dominant receptors of Cs^+ in the rocks. This topic is proposed for further research in the project (Koons, Helmke, and Jackson, in preparation; Koons, Abdel-Kader, Jackson, and Helmke, in preparation).

To evaluate the retention of radioactive waste elements by shales, samples of coarsely ground shales were treated with various reagents, the residues separated into different size fractions and analyzed by INAA.

Figure 1: Relative depletion and addition of selected elements in weathered diabase. Percent gains and losses are calculated relative to aluminum for the transition fresh rock-weathered rock using sample D-3 as the fresh rock and sample D-27 as the weathered rock.

Figure 2: Concentrations of selected elements in size fractions of sample D-1. Concentrations are shown as ratios to the concentration of each element in the coarsest size fraction for ease in displaying data.

Samples were treated in succession with H_2O , 1.0 M $\text{NaC}_2\text{H}_3\text{O}_2$ at pH 5, hot H_2O_2 , a mixture of sodium citrate, bicarbonate, and dithionite to remove iron oxides (CBD treatment) and 0.1 M HF. More than 70% of the total Cs^+ originally present in the whole rock remained in the $< 2.0 \mu\text{m}$ fraction after all of the treatments (Fig. 3) and more than 85% remained in the $< 5.0 \mu\text{m}$ fraction. This indicates that the Cs^+ in shales is held strongly in the fine-grained, crystalline minerals of shales. Additional research is proposed to identify the host phases (Stam, Helmke, and Jackson, in preparation).

This finding of strong Cs^+ retention in rocks and their weathering products is important because of the abundance of $^{137}\text{Cs}^+$ in fission products. Although the neodymium from plutonium has been shown to have remained in place for two billion years in sandstone at the natural fission reactor at Oklo (Gabon), the retention of $^{137}\text{Cs}^+$ for the 300 years or so in rocks is important in the disposal of wastes from nuclear fuel rod processing as well as military nuclear wastes.

Figure 3. Percent of total Cs in the rock remaining in various size fractions after treatment with H₂O, 1.0 M NaC₂H₃O₂ at pH 5, hot H₂O₂, a mixture of sodium citrate, bicarbonate, and dithionite to remove iron oxides (CBD treatment), and 0.1 M HF.

c. Layer sequence of phyllosilicate structures by high resolution electron microscopy in relation to cation fixation. To examine the structural layers of clays, high resolution electron microscopy (HREM) of clay samples was carried out as follows: the clay samples were exchange saturated with a fixing or non-fixing cation species such as K^+ , Cs^+ , or Mg^{2+} . The clay was dried, embedded in epoxy, and thin-sectioned perpendicular to (001) planes of the clay particles by a diamond knife-equipped ultramicrotome (UM). The thin sections were coated with carbon in a vacuum evaporator. To observe the electron optical images of the sequences of (001) planes by high resolution transmission electron microscopy, the thin sections were positioned with the planes at the Bragg angle with reference to the electron beam, an orientation almost parallel with the beam. The first order diffraction component was focused with the primary beam to obtain a diffraction contrast image of each fringe corresponding to a crystal layer. In this way, a sequence of fringes representing the individual crystal layers in a particle is simultaneously recorded as an electron micrograph (Brown and Jackson, 1973). Micrographs made before and after an appreciable irradiation from the electron beam revealed images of the 7Å structural plane spacings of chloritized materials, representing the interlayer hydroxyl to layer hydroxyl (002) electron density nodes. Loss of the images at 7Å intervals and reenforcement of those at 14Å intervals was caused by heating in the electron beam.

Micaceous occlusions in kaolinites were observed by ultramicrotomy and high resolution electron microscopy (Lee, Jackson, and Brown, 1975a). Establishment by these UM-HREM studies of the presence of micaceous vermiculite in clays of highly weathered kaolinitic soils helps to explain

properties important to fixation by kaolinitic clays of cations such as $^{137}\text{Cs}^+$ in radioactive wastes. Electron optical fringes (images) of wedges and frayed-edges were photographed in weathered micaceous vermiculite samples (Lee, Jackson, and Brown, 1975b). This provides, for the first time, a firm scientific visual model for the crystal disorder of 1:1 and 2:1 layer mixing. The study provides a clearer understanding of the cation fixing sites in natural clays for fission products such as $^{137}\text{Cs}^+$. The wedge shaped cation fixation structures ^{are} thought to be specific for $^{137}\text{Cs}^+$ sorption and fixation (Mokma et al., 1973). The above observations also indicated the presence of hydroxy metal interlayers which probably decrease the Cs^+ fixation capacity by lowering the layer charge (Dolcater et al., 1972) as well as by propping the interlayers open. These hydroxy interlayers may be active in adsorption of divalent cations including those of the $^{90}\text{Sr}^{2+}$ type (Kinniburgh, Jackson, and Syers, 1976). Micaceous argillaceous sediments (such as shales which have been used as $^{137}\text{Cs}^+$ waste adsorbants), were found to contain extremely thin crystal packets of mica (a few 10A-layers thick) within the particles when a series of samples was studied by ultramicrotomy-high resolution electron microscopy (Fig. 1, Progress Report C00-1515-56, gives an example). These packets of mica layers have high specific surface which may be responsible for sorption and fixation of cations such as $^{137}\text{Cs}^+$ in the interpacket spaces. Electron micrographs of a series of the argillaceous sediments have been made, and examination of additional samples is proposed.

III. Aerosolic minerals in dusts which fix radioactive nuclear fission products

Radiotracer studies have shown that aerosol dusts (Jackson et al., 1973; Jackson, 1974) of the atmospheric weather zone (troposphere) are active in sequestering of fission products, particularly $^{137}\text{Cs}^+$ (Syers et al., 1972), as summarized in C00-1515-56. Major differences in mean oxygen isotopic ratios of aerosol size quartz (1-10 μm diameter) occurs between different areas of the earth, as will be discussed in IIIc.

a. Oxygen isotopic tracing dust origin. Aerosolic dusts containing micaceous vermiculite are deposited in Hawaii (Jackson et al., 1971) and in Pacific pelagic sediments (Clayton et al., 1972). These dusts contain quartz having oxygen isotopic ratios ($\delta^{18}\text{O} = 18 \pm 2$) intermediate between those of igneous-metamorphic quartz and quartz crystallized at lower temperatures such as chert in sediments (Jackson, 1977). A composite mixture of these two sources in silty sediments and soils formed thereon was postulated as the source of atmospheric dusts. To test this, the oxygen isotopic ratios ($\delta^{18}\text{O}$) of whole shale quartz, and of the 1-10 μm fraction (long range aerosol size) of shale quartz, were determined for the geologic column in the U.S.A. (Churchman, Clayton, Sridhar, and Jackson, 1976). A range, $\delta^{18}\text{O} = 20 \pm 3$ o/oo, was found for the 1-10 μm quartz fraction of marine shales, which is an intermediate range indicated for dust. Further mixing of the two sources, as the shales were reworked by fluvial, eolian and glacial processes and subsequent soil formation and wind erosion, appears to be responsible for narrowing the composite oxygen isotopic ratio to the range found for several fine silt quartz systems such as in Pacific sediments (above). An improvement in the quartz isolation procedure was

made, by the use of boric acid to remove traces of aluminum fluorides formed in the H_2SiF_6 treatment (Jackson, Sayin, and Clayton, 1976). In additional isolations, the 1-10 μm quartz fraction of loess in a high-dolomite area of Wisconsin has oxygen isotopic ratios closer to that of chert, $\delta^{18}\text{O} = 22 \pm 2$ o/oo, while down river (in Mississippi) an increase in the content of quartz of igneous rock origin lowered the loess quartz numbers to 17.5 ± 1 o/oo.

The quartz oxygen isotopic composition varies greatly with grain size (Clayton et al., 1972; Sridhar, Jackson, and Clayton, 1975; Jackson, 1977). This variation is mainly a function of diversity of source (igneous-metamorphic mixed with low temperature sources) rather than oxygen isotopic exchange in an outer skin, as shown by stripping off of the outer 35 to 45% of the quartz with HF. Use of quartz oxygen isotopic composition as a guide to provenance of aerosol dust would be impaired if the isotopic composition changed much under the environmental conditions in the deposit; however, research has shown that this is not a problem under several thousand feet of burial or intensive surficial weathering (Clayton, Jackson, and Sridhar, 1977, submitted). Quartz oxygen isotopic ratio, therefore, appears to be a reliable indicator of provenance.

b. Scanning electron microscopic identification of dust components.

Euhedral morphology of chert particles and overgrowths on quartz grains were shown by scanning electron microscopy (Sayin and Jackson, 1975) and therefore quartz particle morphology, to a certain extent, may be used as an indicator of provenance for aerosol dusts and soil silts. Examination of the 1-10 μm quartz of soil sediments generally revealed few chert aggregates, but more blades and chips that may have formed as overgrowths on quartz in sediments.

and fractured into the aerosol fraction (Sridhar et al., 1977, submitted). Biogenic silica (diatomaceous) fragments were found in dusts of the tropical North Atlantic area (Jackson, Clayton, Mayeda, Gillette and Sridhar, in preparation). This observation indicates the need for heavy liquid separation as the final step in quartz isolation.

c. Major aerosolic dust systems. An opportunity for gaining a major insight into large scale dust systems was presented through cooperation with a program of the National Center for Atmospheric Research (NCAR, supported by NSF) and the Soil Conservation Service (SCS, USDA), with relatively limited commitment from COO-EY-76-S-02-1515 resources (0.1 man-year equivalent). Tropospheric aerosols from major dust storms arising in cultivated agricultural areas in western Texas and adjacent areas of Arizona, New Mexico, Oklahoma and Colorado were collected by NCAR with a ground-based airturbine sampler with stack 3-m high and by airplane-borne dust samplers. Also, composite soil samples from 13 soil mapping groups strongly affected by wind erosion were collected by the SCS. The quartz in the 1-10 μm fraction from the soil samples gave oxygen isotopic ratios ($\delta^{18}\text{O}$) in the range of 19.6 ± 0.3 o/oo (Sridhar, Jackson, Clayton, Gillette, and Hawley, 1977, submitted). That of the dusts fell in the interval 18.4 ± 0.8 o/oo (Gillette, Clayton, Mayeda, Jackson, and Sridhar, 1977, submitted). The slightly lower value was attributed to wind abrasion of coarser particles into the 1-10 μm fraction. The oxygen isotopic ratios of the aerosol-sized quartz from the soils and dusts indicate that the southwest U.S.A. may serve as a reservoir of dusts that move northeast through the mid-continent (Jackson et al., 1973). The micaceous vermiculite of dusts

is able to adsorb and fix radioactive ions from the air (Syers et al., 1972) as well as nucleate rain and hail. Some of the dust may enter Easterly winds and rain out into the North Pacific Ocean as pelagic sediments and on surface soils of Hawaiian mountain tops as aerosolic minerals ($\delta^{18}O = 18.3 \pm 0.2$ o/oo was found for the 1-10 μm quartz in soils and lake sediments of Hawaii; Sridhar et al., 1977, submitted), just as do the dusts from Asia coming in on the Westerly winds (Syers et al., 1969; Jackson et al., 1971; Clayton et al., 1972).

The oxygen isotopic ratios ($\delta^{18}O$) of whole shale quartz, and of the fine silt quartz fraction (1-10 μm ; long range aerosol size) of shale quartz, were determined (20.7 ± 1.8 o/oo) for 30 marine shale quartz fine silts representative of soil parent material (via glacial, fluvial, and eolian processes) from the Phanerozoic geologic column in the midcontinental U.S.A. (Churchman, Clayton, Sridhar, and Jackson, 1976). The range and standard deviation is wider than for the aerosol size quartz of the Pacific and Texas areas, suggestive of more homogenization of the aerosols by wind mixing (Table 2). The dynamics of water and wind erosion and soil formation which are responsible for narrowing the quartz oxygen isotopic ratio range by compositing from diverse sources also account for the nearly ubiquitous occurrence of $^{137}Cs^+$ fixing micaceous vermiculite in soils and sediments. Eolian deposition of soil horizons over other types of parent material has been noted in Hawaii (Jackson et al., 1971) and North Carolina (Syers et al., 1969), a subject proposed for further study for isolates already prepared from soils of Germany and of Wisconsin (Abdel-Kader, Schlichting, Jackson, and Clayton, in preparation).

Table 2 -- Mean oxygen isotopic ratios of aerosol-sized quartz isolated from dusts, soils and sediments (from Jackson, 1977)

Area	Kind of soil or sediment	Quartz size range (μm)	Number of samples (mean of)	Mean $\delta^{18}\text{O}$ (‰)	Reference
Mid-USA	Shales	1-10	30	20.7 $\pm$ 1.8	Churchman <u>et al.</u> , 1976
	"	ws*	31	19.1 $\pm$ 2.2	" " " "
SW. USA	Soils	1-10	13	19.6 $\pm$ 0.3	Sridhar <u>et al.</u> , 1977
		1-10	18	19.0 $\pm$ 0.2	" " " "
	Dusts	1-10	21	18.4 $\pm$ 0.8	Gillette <u>et al.</u> , 1977
E. Cent. TX, AZ	Soils	1-10	5	17.7 $\pm$ 0.6	Sridhar <u>et al.</u> , 1977
Hawaii (4 Islands) [†]	Soils	1-10	5	18.3 $\pm$ 0.2	Sridhar <u>et al.</u> , 1977
		ws	25	17.6 $\pm$ 0.5	Jackson <u>et al.</u> , 1971
N. Pacific	Pelagic	ws [§]	8	17.5 $\pm$ 0.5	Clayton <u>et al.</u> , 1972
S. Pacific	Pelagic	2-5	7	15.1 $\pm$ 1.5 [#]	" " " "
Australia, Victoria	Loess in basaltic soils	2-5	10	14.9 $\pm$ 0.5	Mokma <u>et al.</u> , 1972
		5-20	11	14.5 $\pm$ 0.2	" " " "
SW. USA	Soils	ws	8	14.7 $\pm$ 0.9	Sridhar <u>et al.</u> , 1977
New Zealand					
N. Island	In till	5-20	5	13.6 $\pm$ 1.0	Mokma <u>et al.</u> , 1972
S. Island	" "	5-20	7	13.2 $\pm$ 0.2	" " " "
S. Island	" "	2-5	7	13.3 $\pm$ 0.1	" " " "
S. Island	Glacial dust bands	ws	3	13.5 $\pm$ 0.4	" " " "
S. Africa	Soils and sediments	1-10	28	12.2 $\pm$ 2.1	le Roux <u>et al.</u> , 1977

* Whole quartz from samples.

[†] Including for 1-10 μm two lake sediments from on top of Mauna Kea, and excluding hydrothermal area for ws.

[§] Weighted average calculated from size fractions, excluding Gulf of Alaska.

[#] 9° 13' to 58° 26' S. latitude.

Aerosolic dusts containing micaceous vermiculite are deposited in Hawaii (Jackson et al., 1971) and in Pacific pelagic sediments (Clayton et al., 1972). These dusts contained quartz having oxygen isotopic ratios ($\delta^{18}\text{O} = 17.6 \pm 0.5$ and 17.5 ± 0.5 o/oo, respectively, in the North Pacific area (Jackson, 1976). In the South Pacific area, the quartz of both in dusts and pelagic sediments had lower values (12-15 o/oo) (Mokma et al., 1972). Analyses of 1-10 μm quartz of 28 soils and sediments of South Africa (le Roux, Clayton, and Jackson, 1977) gave a mean $\delta^{18}\text{O}$ of 12.2 ± 2.1 o/oo for part of this Southern Hemisphere continent in the latitude of the South Pacific area, so the trend may be global. Both sets of values are intermediate between those of igneous-metamorphic (high temperature, low $\delta^{18}\text{O}$) quartz and quartz of chert in sediments (low temperature origin, high $\delta^{18}\text{O}$), but in different proportions in sediments of the two Hemispheres (Fig. 4). A composite mixture of these two sources in dusts, silty sediments, and soils formed thereon is postulated as the source of atmospheric dusts.

The difference in oxygen isotopic ratios of 1-10 μm quartz between the Northern and Southern Hemispheres is explained (Jackson, 1977) as follows: During the several hundred million years of the Phanerozoic Eon, the Northern Hemisphere continents were located in tropical and equatorial latitudes. The soils were subject to the usual intense desilication at these latitudes, with an accompanying discharge of soluble $\text{Si}(\text{OH})_4$ into rivers and oceans where biogenic silica was deposited and from which low-temperature quartz gradually formed. As the present Northern Hemisphere continents were carried northward across the equator by plate tectonics, during and subsequent to the Cretaceous Period, the ocean sediments were uplifted to form great continental plains with their abundance of low-

Fig. 4. Divergence of Northern and Southern Hemisphere quartz oxygen isotopic ratios ($\delta^{18}\text{O}$) of long range aerosol dust size (1-10 μm) particles. --- = $\pm$ sigma. From Jackson (1977).

temperature, high $\delta^{18}\text{O}$ quartz. Some land areas in the Southern Hemisphere were part of a frigid South Polar supercontinent, Gondwanaland, and associated seas in late Paleozoic time. Glacial and fluvial erosion of predominantly igneous and metamorphic rocks, with low $\delta^{18}\text{O}$ values of quartz from the mountains of continental sutures, carried silts onto continental shelves during the late Carboniferous, Permian, and Triassic periods (le Roux et al., 1977). These continental shelves were uplifted into lands as plate motions carried the Southern Hemisphere continents northward into their present positions, along with the low $\delta^{18}\text{O}$ quartz in their silty sediments (Jackson, 1976). Of course, large portions of the sediments of these continents were formed before and after the Gondwanaland glacial periods and some areas extended into warm climates (coal beds associated) in time of Gondwanaland's existence. The sediments laid down at those times and places contain quartz with oxygen isotopic ratios resembling Northern Hemisphere quartz (Jackson, 1976), a subject proposed for further study (Violante, Clayton, and Jackson, in preparation).

d. Neutron activation analytical tracing of dust origin. Multielement analysis of quartz was investigated to provide evidence supportive of the oxygen isotopic ratio results. The fine-silt quartz fraction (1-10 μm) for marine shales from the midcontinental U.S.A. were analyzed by neutron activation analysis. Of the 20 elements measured for shales from the Cretaceous period, only La, Sm, Ba, and Hf show trends of systematic variations in concentrations with increasing distance from the western shoreline of the Cretaceous sea in the area now Montana, analogous to the results of oxygen isotope analysis of the fine silt quartz fraction. No trends in trace element concentrations were found in silt size quartz samples from Devonian shales. The element concentrations in fine silt, quartz samples are very low and can be easily influenced by slight sample contamination with ordinary dust or variations in the procedures used to isolate the quartz. Complete development of this approach to identify and trace the origin of fine silt size quartz, which is a resistant tracer of long range aerosolic dust, would require identification of the host mineral phases of trace elements in fine silt size quartz samples and their behavior during the quartz isolation procedure.

Under contract AT(11-1)-1515, initiated June 1, 1965, and E(11-1)-1515.

1. Roth, C. B., M. L. Jackson, J. M. de Villiers, and V. V. Volk 1967 SURFACE COLLOIDS ON MICACEOUS VERMICULITE. In *Soil Chemistry and Soil Fertility*, G. V. Jacks, Editor, Trans. Commissions II and IV, Intl. Soc. Soil Sci., (Aberdeen), pp. 217-221. (Paper COO-1515-3)
2. de Villiers, J. M., and M. L. Jackson 1967 ALUMINOUS CHLORITE ORIGIN OF pH-DEPENDENT CATION EXCHANGE CAPACITY VARIATIONS. *Soil Sci. Soc. Amer. Proc.* 31:614-619. (Paper COO-1515-5)
3. Roth, C. B., M. L. Jackson, E. G. Lotse, and J. K. Syers 1968 FERROUS-FERRIC RATIO AND CEC CHANGES ON DEFERRATION OF WEATHERED MICACEOUS VERMICULITE. *Israel J. Chem.* 6:261-273. (Paper COO-1515-13)
4. Jackson, M. L. 1968 WEATHERING OF PRIMARY AND SECONDARY MINERALS IN SOILS. *Trans. Intl. Soc. Soil Sci.*, 9th Congr. (Adelaide) 4:281-292. (Paper COO-1515-14)
5. Dolcater, D. L., E. G. Lotse, J. K. Syers, and M. L. Jackson 1968 CATION EXCHANGE SELECTIVITY OF SOME CLAY-SIZED MINERALS AND SOIL MATERIALS. *Soil Sci. Soc. Amer. Proc.* 32:795-798. (Paper COO-1515-15)
6. Syers, J. K., S. L. Chapman, M. L. Jackson, R. W. Rex, and R. N. Clayton 1968 QUARTZ ISOLATION FROM ROCKS, SEDIMENTS AND SOILS FOR DETERMINATION OF OXYGEN ISOTOPIC COMPOSITION. *Geochim. Cosmochim. Acta* 32:1022-1024. (Paper COO-1515-16)
7. Rex, R. W., J. K. Syers, M. L. Jackson, and R. N. Clayton 1969 EOLIAN ORIGIN OF QUARTZ IN SOILS OF HAWAIIAN ISLANDS AND IN PACIFIC PELAGIC SEDIMENTS. *Science* 163:277-279. (Paper COO-1515-21)
8. Syers, J. K., M. L. Jackson, V. E. Berkheiser, R. N. Clayton, and R. W. Rex 1969 EOLIAN SEDIMENT INFLUENCE ON PEDOGENESIS DURING THE QUATERNARY. *Soil Sci.* 107:421-427. (Paper COO-1515-22)
9. Roth, C. B., M. L. Jackson, and J. K. Syers 1969 DEFERRATION EFFECT ON STRUCTURAL FERROUS-FERRIC IRON RATIO AND CEC OF VERMICULITES AND SOILS. *Clays Clay Minerals* 17:253-264. (Paper COO-1515-23)
10. Mokma, D. L., J. K. Syers, and M. L. Jackson 1970 CATION EXCHANGE CAPACITY AND WEATHERING OF MUSCOVITE MACRO-FLAKES. *Soil Sci. Soc. Amer. Proc.* 34:146-151. (Paper COO-1515-17)
11. Dolcater, D. L., J. K. Syers, and M. L. Jackson 1970 TITANIUM AS FREE OXIDE AND SUBSTITUTED FORMS IN KAOLINITES AND OTHER SOIL MINERALS. *Clays Clay Minerals* 18:71-79. (Paper COO-1515-25)
12. Sridhar, K., M. L. Jackson, and J. K. Syers 1970 MICACEOUS VERMICULITE BASAL CLEAVAGES WITH BLISTER-LIKE LIFTING OF LAYERS AS A FUNCTION OF EXCHANGEABLE CATION CHARGE AND HYDRATION. *Abstracts*, Geol. Soc. Amer. meeting, Milwaukee, WI, pp. 692-693.
13. Jackson, M. L., T. W. M. Levelt, J. K. Syers, R. W. Rex, R. N. Clayton, G. D. Sherman, and G. Uehara 1971 GEOMORPHOLOGICAL RELATIONSHIPS OF TROPOSPHERICALLY-DERIVED QUARTZ IN SOILS OF THE HAWAIIAN ISLANDS. *Soil Sci. Soc. Amer. Proc.* 35:515-525. (Paper COO-1515-27)
14. Kinniburgh, D. G., J. K. Syers, and M. L. Jackson 1971 SELECTIVE SORPTION AND EXCHANGE OF Ca^{2+} AND Sr^{2+} BY OXIDES AND HYDROUS OXIDES OF IRON AND ALUMINUM. *Agronomy Abstracts*, New York meeting, NY, pp. 123-124.
15. Sridhar, K., M. L. Jackson, and J. K. Syers 1971 INTERACTION OF FIXING CATIONS WITH BLISTERS ON MICACEOUS VERMICULITE CLEAVAGES PRODUCED BY OSMOTIC SWELLING. *Abstracts 20th Clay Min. Conf.*, Rapid City, SD, pp. 32.
16. Dolcater, D. L., M. L. Jackson, and J. K. Syers 1972 CATION EXCHANGE SELECTIVITY IN MICA AND VERMICULITE. *Amer. Mineral.* 57:1823-1831. (COO-1515-24)
17. Syers, J. K., D. L. Mokma, M. L. Jackson, D. L. Dolcater, and R. W. Rex 1972 MINERALOGICAL COMPOSITION AND CESIUM-137 RETENTION PROPERTIES OF CONTINENTAL AEROSOLIC DUSTS. *Soil Sci.* 113:116-123. (COO-1515-28)
18. Clayton, R. N., R. W. Rex, J. K. Syers, and M. L. Jackson 1972 OXYGEN ISOTOPE ABUNDANCE IN QUARTZ FROM PACIFIC PELAGIC SEDIMENTS. *J. Geophys. Res.* 77:3907-3915. (COO-1515-29)
19. Mokma, D. L., J. K. Syers, M. L. Jackson, R. N. Clayton, and R. W. Rex 1972 AEOLIAN ADDITIONS TO SOILS AND SEDIMENTS IN THE SOUTH PACIFIC AREA. *J. Soil Sci.* 23:147-162. (COO-1515-32)
20. Sridhar, K., M. L. Jackson, and J. K. Syers 1972 CATION AND LAYER CHARGE EFFECTS ON BLISTER-LIKE OSMOTIC SWELLING OF MICACEOUS VERMICULITE. *Amer. Mineral.* 57:1832-1848. (COO-1515-37)
21. Jackson, M. L., F. R. Gibbons, J. K. Syers, and D. L. Mokma 1972 EOLIAN INFLUENCE ON SOILS DEVELOPED IN A CHRONO-SEQUENCE OF BASALTS OF VICTORIA, AUSTRALIA. *Geoderma* 8:147-163. (COO-1515-43)
22. Mokma, D. L., M. L. Jackson, J. K. Syers, and P. R. Stevens 1973 MINERALOGY OF A CHRONOSEQUENCE OF SOILS FROM GREYWACKE AND MICA-SCHIST ALLUVIUM, WESTLAND, NEW ZEALAND. *New Zeal. J. Sci.* 16:769-798. (COO-1515-30)
23. Mokma, D. L., M. L. Jackson, J. K. Syers, and F. R. Gibbons 1973 MINERALOGY AND RADIOISOTOPE RETENTION PROPERTIES OF A CHRONOSEQUENCE OF SOILS DEVELOPED IN BASALTS OF VICTORIA, AUSTRALIA. *J. Soil Sci.* 24:199-214. (COO-1515-33)
24. Jackson, M. L., S. Y. Lee, J. L. Brown, I. B. Sachs, and J. K. Syers 1973 SCANNING ELECTRON MICROSCOPY OF HYDROUS METAL OXIDE CRUSTS INTERCALATED IN NATURALLY WEATHERED MICACEOUS VERMICULITE. *Soil Sci. Soc. Amer. Proc.* 37:127-131. (COO-1515-34)
25. Brown, J. L., and M. L. Jackson 1973 CHLORITE EXAMINATION BY ULTRAMICROTOMY AND HIGH RESOLUTION ELECTRON MICROSCOPY. *Clays Clay Miner.* 21:1-7. (COO-1515-35)
26. Sridhar, K., and M. L. Jackson 1973 FIXING CATION INTERACTION WITH BLISTER-LIKE OSMOTIC SWELLING ON VERMICULITE CLEAVAGES. *Clays Clay Miner.* 21:369-377. (COO-1515-42)
27. Jackson, M. L., D. A. Gillette, E. F. Danielsen, I. H. Blifford, R. A. Bryson, and J. K. Syers 1973 GLOBAL DUST-FALL DURING THE QUATERNARY AS RELATED TO ENVIRONMENTS. *Soil Sci.* 116:135-145. (COO-1515-49)

28. Jackson, M. L. 1974 EOLIAN ADDITION TO SOILS. Intl. Soil Sci. Soc. Trans., 10th Congr. (Moscow) 6(2):458-465. (COO-1515-54)
29. Jackson, M. L., and K. Sridhar 1974 SCANNING ELECTRON MICROSCOPIC AND X-RAY DIFFRACTION STUDY OF NATURAL WEATHERING OF PHLOGOPITE THROUGH VERMICULITE TO SAPONITE. Soil Sci. Soc. Amer. Proc. 38:833-847. (COO-1515-48)
30. Lee, S. Y., M. L. Jackson, and I. B. Sachs 1974 FISSION PARTICLE TRACKS IN MICAS AND MICACEOUS VERMICULITES AS RELATED TO CHEMICAL WEATHERING AND CATION EXCHANGE PROPERTIES. Soil Sci. Soc. Amer. Proc. 38:423-428. (COO-1515-45)
31. Sridhar, K., and M. L. Jackson 1974 LAYER CHARGE DECREASE BY TETRAHEDRAL CATION REMOVAL AND SILICON INCORPORATION DURING NATURAL WEATHERING OF PHLOGOPITE TO SAPONITE. Soil Sci. Soc. Amer. Proc. 38:847-851. (COO-1515-55)
32. Veith, J. A., and M. L. Jackson 1974 IRON OXIDATION AND REDUCTION EFFECTS ON STRUCTURAL HYDROXYL AND LAYER CHARGE IN AQUEOUS SUSPENSIONS OF MICACEOUS VERMICULITES. Clays Clay Miner. 22:345-353. (COO-1515-46)
33. Kinniburgh, D. G., J. K. Syers, and M. L. Jackson 1975 SPECIFIC SORPTION OF TRACE AMOUNTS OF CALCIUM AND STRONTIUM BY HYDROUS OXIDES OF IRON AND ALUMINUM. Soil Sci. Soc. Amer. Proc. 39:464-470. (COO-1515-38)
34. Lee, S. Y., M. L. Jackson, and J. L. Brown 1975a MICACEOUS OCCLUSIONS IN KAOLINITE OBSERVED BY ULTRAMICROTOMY AND HIGH RESOLUTION ELECTRON MICROSCOPY. Clays Clay Miner. 23:125-129. (COO-1515-44)
35. Lee, S. Y., M. L. Jackson, and J. L. Brown 1975b MICACEOUS VERMICULITE, CLAUCONITE, AND MIXED-LAYER KAOLINITE-MONTMORILLONITE EXAMINATION BY ULTRAMICROTOMY AND HIGH RESOLUTION ELECTRON MICROSCOPY. Soil Sci. Soc. Amer. Proc. 39:793-800. (COO-1515-51)
36. Sayin, M., and M. L. Jackson 1975 SCANNING ELECTRON MICROSCOPY OF CHERTS IN RELATION TO THE OXYGEN ISOTOPIC VARIATION OF SOIL QUARTZ. Clays Clay Miner. 23:365-368. (COO-1515-70)
37. Sridhar, K., M. L. Jackson, and R. N. Clayton 1975 QUARTZ OXYGEN ISOTOPIC STABILITY IN RELATION TO ISOLATION FROM SEDIMENTS AND DIVERSITY OF SOURCE. Soil Sci. Soc. Amer. Proc. 39:1209-1213. (COO-1515-59)
38. Kinniburgh, D. G., K. Sridhar, and M. L. Jackson 1976 SPECIFIC ADSORPTION OF ZINC AND CADMIUM BY IRON AND ALUMINUM HYDROUS OXIDES. Symposium Proceedings, "The fifteenth Hanford life sciences symposium on biological implications of metals in the environment," Hanford, WA, Sept. 29-Oct. 1., 1975. USERDA, Oak Ridge, TN, pp. (COO-1515-72)
39. Henderson, J. H., H. E. Doner, R. M. Weaver, J. K. Syers, and M. L. Jackson 1976 CATION AND SILICA RELATIONSHIPS OF MICA WEATHERING TO VERMICULITE IN CALCAREOUS HARPS SOIL. Clays Clay Miner. 24:93-100. (COO-1515-58)
40. Churchman, G. J., R. N. Clayton, K. Sridhar, and M. L. Jackson 1976 OXYGEN ISOTOPIC COMPOSITION OF AEROSOL SIZED QUARTZ IN SHALES. J. Geophys. Res. 81:381-386. (COO-1515-53)
41. Jackson, M. L., M. Sayin, and R. N. Clayton 1976 HEXAFLUROSILICIC ACID REAGENT MODIFICATION FOR QUARTZ ISOLATION. Soil Sci. Soc. Amer. J. 40:958-960. (COO-1515-65)
42. Jackson, M. L., S. Y. Lee, F. C. Ugolini, and P. A. Helmke 1977 AGE AND URANIUM CONTENT OF SOIL MICAS FROM ANTARCTICA BY THE FISSION PARTICLE TRACK METHOD. Soil Sci. 123:241-248. (COO-1515-71)
43. Kinniburgh, D. G., M. L. Jackson, and J. K. Syers 1976 ADSORPTION OF ALKALINE EARTH, TRANSITION, AND HEAVY METAL CATIONS BY HYDROUS OXIDES OF IRON AND ALUMINUM. Soil Sci. Soc. Amer. J. 40:796-799. (COO-1515-52)

Manuscripts Accepted for Publication

44. Lee, S. Y., and M. L. Jackson 1977 SURFACE CHARGE DENSITY DETERMINATION BY ²³⁵U FISSION PARTICLE TRACK METHOD. Clays Clay Miner. 25: (COO-1515-61)
45. Jackson, M. L. 1977 OXYGEN ISOTOPIC RATIOS IN QUARTZ AS AN INDICATOR OF PROVENANCE OF DUST. (Symposium volume, A.A.A.S., presented at Denver, CO meeting Feb. 22-23, 1977) (COO-1515-78)

Manuscripts Submitted for Publication

1. Clayton, R. N., M. L. Jackson, and K. Sridhar 1977 QUARTZ SILT RESISTANCE TO ISOTOPIC EXCHANGE UNDER BURIAL AND INTENSE WEATHERING CONDITIONS. Geochim. Cosmochim. Acta (COO-1515-66)
2. Gillette, D. A., R. N. Clayton, T. K. Mayeda, M. L. Jackson, and K. Sridhar 1977 TROPOSPHERIC AEROSOLS FROM SOME MAJOR DUST STORMS OF SOUTHWESTERN UNITED STATES. J. Appl. Metero. (COO-1515-77)
3. Kinniburgh, D. G., and M. L. Jackson 1977 ADSORPTION OF Hg(II) BY IRON HYDROUS OXIDE GEL. Soil Sci. Soc. Am. J. 41: (COO-1515-64)
4. Koons, R. D., and P. A. Helmke 1977 INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS OF CCRMP STANDARD SOILS SO-1, SO-2, SO-3, and SO-4. Soil Sci. Soc. Am. J. (COO-1515-85)
5. le Roux, J., R. N. Clayton, and M. L. Jackson 1977 OXYGEN ISOTOPIC ABUNDANCE IN QUARTZ FINE SILT FROM SEDIMENTS AND SOILS OF SOUTHERN AFRICA. Geochim. Cosmochim. Acta (COO-1515-62)
6. Sridhar, K., M. L. Jackson, R. N. Clayton, D. A. Gillette, and J. W. Hawley 1977 OXYGEN ISOTOPIC RATIOS OF QUARTZ FROM WIND-EROSIVE SOILS OF SOUTHWESTERN UNITED STATES IN RELATION TO AEROSOL DUST. Soil Sci. Soc. Am. J. 41: (COO-1515-75)

Reprints & Preprints
Removed

Manuscripts in preparation

1. Abdel-Kader, F. H., E. Schlichting, M. L. Jackson, and R. N. Clayton
1977. Quartz oxygen isotopic composition as a measure of eolian
overlay on various parent materials.
Soil Sci.
2. Jackson, M. L., R. N. Clayton, T. K. Mayeda, D. A. Gillette, and
K. Sridhar
1977. Quartz oxygen isotopic composition of tropospheric aerosols
in the tropical North Atlantic area.
Clays Clay Miner. 26:
3. May, H. M., P. A. Helmke, and M. L. Jackson
1977. Determination of aluminum at the sub-part-per-billion con-
centrations in natural waters by 8-hydroxyquinoline extraction.
Chem. Geol.
4. Kinniburgh, D. G., and M. L. Jackson
1977. Zinc and calcium adsorption on hydrous iron oxide gel.
Soil Sci. Soc. Am. J.
5. Koons, R. D., F. H. Abdel-Kader, and M. L. Jackson
1977. Cesium retention by weathered rocks including kaolinite.
Clays Clay Miner.
6. Stam, A. C., P. A. Helmke, and M. L. Jackson
1977. Neutron activation analysis of trace element differences in
authigenic and detrital quartz in relation to dust origin.
Geochim. Cosmochim. Acta
7. Violante, A., R. N. Clayton, and M. L. Jackson
1977. Quartz oxygen isotopic composition in relation to geologic
age and position in the North and South Hemispheres.
Geoderma
8. Koons, R. D., P. A. Helmke, and M. L. Jackson
1977. Retention fission products by soils and weathered rocks.
Soil Sci.

Contract E(11-1)-1515 of
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION WITH THE UNIVERSITY OF WISCONSIN

Principal Investigator: Marion L. Jackson

Department of Soil Science, University of Wisconsin, Madison, WI 53706

Phone: 608+262-0562 or 608+262-2633

COO-1515	Sent		Author, Journal, Content	Manuscript date
	Manu.	Reprint		
1*	x	na	Science Information Exchange form (1965)	15 July 65
2	x	na	Science Information Exchange form (1966)	1 Mar 66
3	x	x	Roth et al., ISSS, Aberdeen (1967) Verm sesquioxide coatings	1 Oct 66
(4)	x	na	Jackson, Trip Report, Aberdeen	1 Oct 66
5	x	x	de Villiers and Jackson, SSSAProc. (1967) Al/(OH) ₂ pH/CEC	9 Jan 67
6	x	na	Technical Progress Report (1967)	1 Feb 67
(7)	x	na	Renewal Proposal	14 Feb 67
(8)	x	na	Single Column Budget	14 Feb 67
(9)	x	na	Statement of costs	14 Feb 67
(10)	x	na	Equipment report	14 Feb 68
11	x	na	Science Information Exchange form (1967)	14 Feb 67
12	x	na	Science Information Exchange form (1968)	24 Feb 68
13	x	x	Roth et al., Israel J. Chem. (1968) Fe coatings/CEC	30 June 67
14	x	x	Jackson, ISSS, Adelaide (1968) pH/CEC	1 July 67
15	x	x	Dolcater et al., SSSAProc. (1968) CES/mica-verm layer charge	15 Dec 67
16	x	x	Syers et al., Geo.CA (1968) Quartz Isol/H ₂ SiF ₆	14 Feb 68
17	x	x	Mokma et al., SSSAProc. (1970) Muscovite flakes/CEC, coatings	27 Feb 70
18	x	na	Technical Progress Report (1968)	24 Feb 68
19	x	na	Science Information Exchange form (1969)	24 Feb 69
20	x	na	Technical Progress Report (1969)	24 Feb 69
21	x	x	Rex et al., Science (1969) Aerosolic dust/fission	23 Sept 68
22	x	x	Syers et al., Soil Sci. (1969) Dusts/loess/fission	20 Feb 69
23	x	x	Roth et al., CCMIn. (1969) Fe,Al coatings/CEC	6 Jan 69
24	x	x	Dolcater et al., Am. Min. (1972) CES	26 Feb 71
25	x	x	Dolcater et al., CCMIn. (1970) CEC/Ti subst.	27 Feb 70
26	x	na	Technical Progress Report (1970)	28 Feb 70
27	x	x	Jackson et al., SSSAProc. (1971) Dusts/geomor. in HI	26 Feb 71
28	x	x	Syers et al., Soil Sci. (1972) Dusts/ ¹³⁷ Cs sorption	26 Feb 71
29	x	x	Clayton et al., J.Geophys.Re. (1972) Dusts/pelagic sediments	26 Apr 72
30	x	x	Mokma et al., NZJSci. (1973) Chrono./ ¹³⁷ Cs sorption	26 Feb 71
31	x		Mokma et al., Hbook Soil Sci. Mica Wea. (Review)	26 Feb 71
32	x	x	Mokma et al., J. Soil Sci. (1972) Eol.dust/S. Pac. area	26 Feb 71
33	x	x	Mokma et al., J. Soil Sci. (1973) ASL dust/isotopes	26 Feb 71
34	x	x	Jackson et al., SSSAProc. (1973) SEM/verm	26 Apr 72
35	x	x	Brown, Jackson, CCMIn. (1973) Ultramicrot./layers	26 Apr 72
36	x	na	Technical Progress Report (1968-71)	26 Feb 71
37	x	x	Sridhar et al., Am. Min. (1972) Blisters on verm/cations	26 Apr 72
38	x	x	Kinniburgh et al., SSSAProc. (1975) Sr, Ca sorp/oxides	26 Apr 72
39	x	na	Science Information Exchange Form (1971)	6 Feb 71
40	x	na	Science Information Exchange Form (1972)	6 Apr 72
41	x	na	Technical Progress Report (1972)	26 Apr 72
42	x	x	Sridhar et al., CCMIn. (1973) Blisters on verm/fixing cations	5 Aug 72
43	na	x	Jackson et al., Geoderma (1972) ASL dusts/isotopes	4 Sept 72
44	x	x	Lee et al., CCMIn. (1975) Mica occlusions kaol/ ¹³⁷ Cs fixation	10 July 73
45	x	x	Lee et al., SSSAProc. (1974) ²³⁸ U Fission tracks/dating	29 Oct 72
46	x	x	Veith, Jackson, CCMIn. (1974) Layer charge change/cation ejection	4 Sept 72
47	x	na	Technical Progress Report (1973)	6 Apr 73
48	x	x	Jackson/Sridhar, SSSAProc. (1974) SEM/verm weathering	2 Nov 73
49	x	x	Jackson et al., Soil Sci. (1973) Global dusts/meteorology	4 May 73
50	x	na	Science Information Exchange Form (1973)	16 Apr 73
51	x	x	Lee et al., SSSAProc. (1975) Mica verm/ultramicrotomy	10 Aug 73
52	x	x	Kinniburgh et al., SSSAProc. Transition metal sorption	15 Mar 75
53	x	x	Churchman et al., J.Geophys.R. Source reservoir eolian materials	30 Apr 74
54	x	x	Jackson ISSS (Moscow) (1974) Eolian additions to soils	1 May 73
55	x	x	Sridhar/Jackson SSSAProc. (1974) Verm layer charge decrease	12 Nov 73
56	x	na	Technical Progress Report (1971-74)	29 Apr 74
57	x	na	Science Information Exchange Form (1974)	29 Apr 74

* Numbers refer to published papers, Technical Progress Reports, and Science Information Exchange Forms in the COO-1515-x series. Numbers in () incorrectly used for other than Technical Progress Reports.

x = Submitted to U.S. AEC/ERDA with earlier reports. na = Not applicable.

Key to C00-1515 Report Series (Cont.)

Sent			Author, Journal, Content	Manuscript
C00-1515 Ms.	Re-print			
58*	x	xx	Henderson <u>et al.</u> , <u>CCM</u> (1976), Verm CaCO ₃ /fixing cations	11 April 75
59	x	x	Sridhar <u>et al.</u> , <u>SSSAJ</u> (1975), Isotopic ratio/source	13 March 75
60			Jackson, Lee, <u>CCM</u> , Chlor-mica ultramicro/elect. mic.	In preparation
61	xx		Lee, Jackson, <u>SSSAJ</u> , Fission particle/layer charge	1 May 76
62			le Roux, Clayton, Jackson, <u>GCA</u> , Oxygen isotopic ratio	1 May 77
63			Stam, Helmke, Jackson, Neutron activation analysis	In preparation
64			Kinniburgh, Jackson, <u>SSSAJ</u> , Hg(II) ³⁶ Cl sorp./Fe	17 Jan. 77
65	x	xx	Jackson, Sayin, Clayton, <u>SSSAJ</u> , H ₂ SiF ₆ reagent/loess	28 Jan. 76
66	x		Clayton, Jackson, Sridhar, <u>GCA</u> , Quartz isotopic resist.	24 Mar. 76
67	x	na	Technical Progress Report (1975)	27 April 75
68	x	na	Science Information Exchange Form (1975)	27 April 75
69			May, Helmke, Jackson, <u>Chem. Geol.</u> , Al determ at 0.1 ppb	21 July 77
70	x	x	Sayin/Jackson, <u>CCM</u> , SEM cherts	12 Feb. 75
71	x	xx	Jackson, Lee, Helmke, <u>Soil Sci.</u> , U cont. fission tra	4 Mar. 76
72	x		Kinniburgh, Sridhar, Jackson, <u>Battelle Conf.</u> , Zn, Cd sorp.	1 Sept. 75
73	x	na	Technical Progress Report (1976)	26 Apr. 76
74	x	na	Science Information Exchange Form (1976)	26 Apr. 76
75			Sridhar <u>et al.</u> , <u>SSSAJ</u> , Oxy. Iso. Ratio/dust TX	10 Jan. 77
76			Jackson, Clayton <u>et al.</u> , Dusts of tropical Atlantic	In preparation
77			Gillette, Jackson <u>et al.</u> , <u>J. Appl. Meteor.</u> , Oxy. Isotopic Ratio dust/TX	10 June 77
78	xx		Jackson, Oxygen Isotopes/dusts	15 June 77
79	xx	na	Technical Progress Report (1974-1977)	26 July 77
80	xx	na	Science Information Exchange Form (1977)	26 July 77
81			Kinniburgh, Jackson, <u>SSSAJ</u> , Radio Ca, Zn	In preparation
82			Koons, Helmke, Cs retention in wea. zone	In preparation
83			Violante, Jackson <u>et al.</u> , <u>Geoderma</u> , Oxy. Iso. Ratio/N-S Hemi.	In preparation
84			Kader, Jackson <u>et al.</u> , Cs retention in clay	In preparation

* Numbers refer to published papers, Technical Progress Reports, and Science Information Exchange Forms.

x = Submitted to U.S. AEC/ERDA with earlier reports.

xx = Sent with Technical Progress Report (C00-1515-79).

na = Not applicable.

EFFORT LEVEL OF PERMANENT PERSONNEL:

Principal Investigator, Marion L. Jackson, 0.25 man-year equivalent, for 12 months (25% of time in year to date, and to end of current term of contract)

Co-Investigator, Philip A. Helmke, 0.15 man-year equivalent, for 12 months (15% of time in year to date, and to end of current term of contract)